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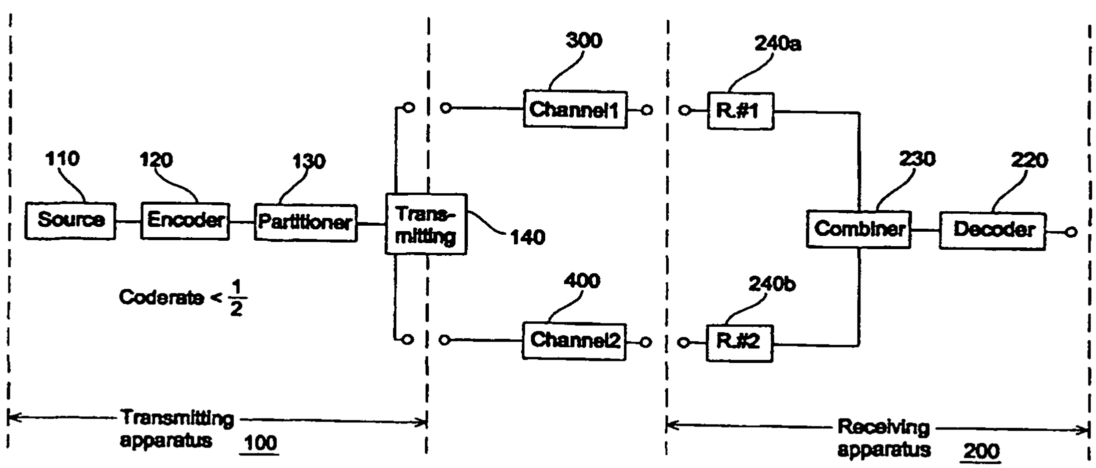

(57) Abstract

An apparatus (100) for transmitting information comprises a bitstream source (110) for providing a bitstream representing the information, a redundancy adding encoder (120) for generating an encoded bitstream, which is arranged to output, for a first number of input bits and a second number of output bits. The apparatus (100) further comprises means (130) for partitioning the second number of output bits into the two portions of output bits and means (140) for transmitting the output bits of the first portion via a first channel (300) and the output bits of the second portion via second channel (400) being spatially different from the first channel (300). An inventive receiving apparatus (200) combines (230) the signals received via the first and second channels (300, 400) and uses both channel signals for channel decoding (220) by removing redundancy.

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Apparatus and Method For Transmitting Information and Apparatus and Method For Receiving Information

Specification

The present invention relates to concepts for digital broadcasting and, in particular, concepts for digital broadcasting suited for fading channels for wireless communication.

Satellite-based broadcasting systems provide an adequate communication link only in rural areas, in which only a small number of e.g. bridges exist. Additionally, rural areas usually do not have skyscrapers. Skyscrapers as well as bridges or, generally, densly built-up areas are obstacles to satellite-based communication systems, since carrier frequencies used for such communication links involve that a channel between a sender, e.g., a satellite, and a receiver, i. e. a mobile or stationary receiver, is characterised by the line of visual contact (line of sight) between the sender and the receiver. If a skyscraper comes into the line of visual contact, i.e., the transmission channel between the satellite and the receiver, which may be positioned in a car, the received signal power will decrease substantially.

Generally, it can be stated that in wireless systems (radio systems), changes in the physical environment cause the channel to fade. These changes include both relative movement between transmitter and receiver and moving scatters/reflectors in the surrounding space. In theoretical studies of wireless systems, the real channels are usually modelled so that they result in trackable analysis. The two major classes of fading characteristics are known as Rayleigh and Rician. A Rayleigh-fading environment assumes no line of sight and no fixed reflectors/scatters. The

expected value of the fading is zero. If there is a line of sight, this can be modelled by Rician-fading, which has the same characteristics as the Rayleigh-fading, except for a non-zero expected radio.

Modern digital broadcasting systems know several means for reducing the impact of a channel fading. These concepts comprise channel coding on the one hand and several kinds of diversity on the other hand. The European standard for digital audio broadcasting (DAB), set out in Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) To Mobile, Portable and Fixed Receivers, ETS 300 401, ETS I - European Telecommunications Standards Institute, Valbonne, France, February 1995, uses differential quadrature phase-shift keying (DQPSK) as modulation technique. The channel encoding process is based on punctured convolutional coding, which allows both equal and unequal error protection. As a mother code, a convolutional code having a code rate of 1/4, a constraint length 7, and octal polynominals is used. The puncturing procedure allows the effective code rate to vary between 8/9 and 1/4. Channel coding by means of punctured convolutional codes is described in "Punctured Convolutional Codes of Rate (n-1)/n and Simplified Maximum Likelihood Decoding", J. Bibb Cain et al., IEEE Transactions on Information Theory, Vol. IT-25, No. 1, January 1979.

Punctured convolutional codes can be used in connection with many modulation techniques, such as OFDM, BPSK, QAM, etc.

Different channel encoding techniques are outlined in "Channel Coding with Multilevel/Phase Signals", Gottfried Ungerboeck, IEEE Transactions on Information Theory, Vol. IT 28, No. 1, pages 55 to 66, January 1982.

Bitstreams encoded by means of a convolutional encoder can be decoded by a decoder, in which the well-known Viterbi algorithm is implemented. This algorithm is capable of using

the channel state information (see P. Hoeher "TCM on Frequency-Selective Length-Mobile Fading Channels", Proc. Tirrenia International Workshop Digital Communication, Tirrenia, Italy, September 1991). The Viterbi algorithm can be modified to provide reliability estimates together with the decoded sequence. This enables soft decoding. By applying a soft-output Viterbi algorithm, an improvement of about 2 dB is obtained in comparison to systems that implement "hard" decision.

With reference to Fig. 6, a simplified overview of a transmitter receiver system described in the European DAB Standard is illustrated. The transmitter receiver system generally comprises a transmitter section 60 and a receiver section 70. The transmitter section 60, in the simplest case, comprises a bitstream source 62, a channel encoder 64 and a transmitter 66. The receiver section 70, in the simplest case, comprises a receiver 72 and a channel decoder 74.

Fig. 7 illustrates a transmitting receiving setup providing for time diversity as well as space diversity. The transmitter section 60′ comprises the bitstream source 62 and the encoder 64 that have already been described with respect to Fig. 6. In addition, the receiver section 60′ comprises a first transmitter 66a and a second transmitter 66b. Both transmitters 66a and 66b are fed by the same signal output by the encoder 64 that is duplicated by a duplicator 67.

To obtain time diversity, a delay element 68 is coupled between the duplicator 67 and the second transmitter 66b.

In the case of satellite communication, the transmitters 66a and 66b are realised by two satellites that reside on different orbital positions spaced apart from each other.

The first channel is defined by the line of sight between

the first transmitter and the receiver, for example, a car, whereas the second channel is defined by the line of sight between the second transmitter 66b and the car that comprises the receiving section 70'. In the scenario, in which the car travels on a street to the right and to the left of which are high buildings, the possibility is increased that the car will receive the transmitted signal from at least one satellite.

When the case is considered, in which the car is driving through a tunnel or under a bridge, the lines of sight to both transmitters 66a and 66b are interrupted. The time diversity method implemented by this system shown in Fig. 7, however, ensures that the receiver will not be affected by the interrupted channel, since the transmission signal is delayed by the delay stage 68. Optimally, no transmission interruption will result, when the delay time is equal to or greater than the travelling time of the car through the tunnel or under the bridge. Thus, the receiving section will, once again, receive the transmission signal sent by the transmitter 66a, when it was under the bridge, via a channel 2. Naturally, the receiving section 70' comprises another delay stage 78. As it is shown in Fig. 7, the delay stage 78 of the receiving section has to be in the channel that has not been delayed in the transmitter section. Thus, the signals at the output of the receivers 72a and 72b are identical, when the delay values of the delay stages 78 and 68 are equal.

A decision stage 79, which is symbolised as a switch in Fig. 7, determines which channel provides the signal with the better signal to noise ratio. When it is determined that channel 1 provides the stronger signal, the decision stage 79 is operative to conduct the signal received by the receiver 72a into the channel decoder 74 When it is determined in block 79 that the signal transmitted over the other channel (channel 2) is the stronger one, the decision stage 79 is operative to conduct the signal received by the

receiver 72b to the channel decoder 74.

To summarise, the system illustrated in Fig. 7 comprises the following essential features:

- the signal output by the encoder 64 is duplicated by the duplicator 67;
- exactly the same signals, whether delayed or not, are transmitted via both channels;
- the signals transmitted over both channels are derived from the bitstream output by the bitstream source 62 in exactly the same way by means of the encoding process carried out in the redundancy adding encoder 64 (repetition code);
- the decision stage 79 compares the signal to noise ratio of both channels and selects the channel in which the signal having the better signal to noise ratio is transmitted;
- the signal transmitted via the other channel is discarded; and
- the channel decoder 74 only uses one channel, i.e., the channel determined by the decision stage 79, for channel decoding.

Besides the technique of channel encoding using a redundancy adding encoder like a convolutional encoder, different types of diversity, e.g., time diversity and space diversity, can be implemented to ease the impact of fading channels.

The bitstream source 62 can be implemented as an audio encoder as defined by ISO-MPEG. It provides a bitstream comprising useful information, i.e., encoded spectral values of a block of audio samples, and side information. To

enhance the robustness of the communication link, a forward error correction encoding is performed by the convolutional encoder 64. In general, the convolutional encoding procedure generates redundancy in the transmitted datastream in order to provide ruggedness against transmission distortion.

Usually, convolutional encoders consist of a specific number of shift registers and a number of XOR gates. The convolutional encoder described in the ETS Standard is a convolutional encoder having a code rate of 1/4. This means that the convolutional encoder produces four output bits for one input bit. As it is well known in the art, each output bit is derived from the current input bit and a specific combination of a certain number of preceding input bits stored in the shift registers. The specific combination of the current input bit and certain preceding input bits for each encoder output bit is defined by the so-called generator polynominals. The octal forms of the generator polynominals defined in the ETS 300 401 are 133, 171, 145 and 133.

The encoded bitstream can be punctured for raising the code rate from 1/4 to another code rate, e.g., 8/9. "Puncturing" means that certain bits in the convolutional encoder output bits are discarded and not forwarded to the transmitter 66. Thus, puncturing operates to again reduce redundancy in an encoded bitstream, which has been added by the convolutional encoder.

The transmitter 66 may comprise usual transmitter elements, such as a QPSK modulator, an IFFT block (IFFT = Inverse Fast Fourier Transform) for performing orthogonal frequency division multiplexing, a guard interval inserter, a synchronisation sequence inserter and modulation means for modulating the signal onto a high frequency carrier.

Analogously, the receiver 72 comprises an HF front end, an analog/digital converter, and a QPSK demodulator. The signal

output by the receiver is input in the decoder 74. The decoder 74 is operative to decode the encoded bitstream output by the receiver 72. In modern communication systems, the decoder 74 implements the above-outlined soft-input Viterbi algorithm. As it has already been outlined, the Viterbi decoder performs a maximum likelihood decoding using the channel state information, which is also called "metric". Different algorithms are known for Rician and Rayleigh channels.

Especially in satellite-based communication systems, design engineers are confronted with strong demands for reducing transmitter power. Reduced transmitter power directly translates into system costs. Generally, the costs for designing and transporting the satellite(s) into its (their) orbital position(s) are directly proportional to the power supply needed on board of the satellite. Higher transmitter power on board of the satellite also means higher energy producing capabilities of the satellite. Thus, it can be stated that, under costs aspects, reducing transmitter power is essential.

Therefore, the system described in Fig. 7 is disadvantageous in that, in the receiver, only one channel is used for retrieving information, whereas the other channel is discarded. In extreme situations, in which one channel has faded totally, no transmitter power from one transmitter, i.e., one satellite, will reach the receiver. Normally, however, the channels will not fade totally. Instead, both channels will fade more or less. Thus, the decision stage 79 has to select one out of two useful signals. When the case is considered that both signals output by the receivers 72a and 72b have identical signal to noise ratios, only one signal is selected, whereby the transmitter power from the satellite transmitting via the other channel is wasted totally.

It is the object of the present invention to provide an

apparatus and method for transmitting information and an apparatus and method for receiving information, which result in better receiver output signal quality and/or reduced transmitter power demands.

This object is attained by an apparatus for transmitting information in accordance with claim 1, an apparatus of receiving information in accordance with claim 11, a method of transmitting information in accordance with claim 20, and a method of receiving information in accordance with claim 30.

The present invention is based on the finding that, although there are two physically different channels both channels are considered as one single channel from the viewpoint of the channel decoder located in the receiving section. This means that the channel decoder in the receiving section does not know that the signals it decodes stem from two physically, i. e. spatially, different channels. However, the inventive system, in fact, provides two different physical channels to allow for time and/or space diversity. The space diversity can be obtained by two terrestrial transmitters, by two satellite transmitters or by one satellite transmitter and one terrestrial transmitter.

In accordance with the present invention, an apparatus for transmitting information comprises a bitstream source for providing a bitstream representing the information. A redundancy adding encoder for generating an encoded bitstream based on the bitstream provided by the bitstream source is arranged to output, for a first number of input bits, a second number of output bits, the second number of output bits having at least twice as many output bits as the first number of input bits, and wherein the second number of output bits includes two portions of output bits, each portion of output bits individually allowing the retrieval of information represented by the first number of input bits, and the first portion of output bits being coded based

on the bitstream in a different way with respect to the second portion of output bits. A means for partitioning receives the output of the redundancy adding encoder and partitions the second number of output bits into the two portions of output bits. Means for transmitting transmit the output bits of the first portion via a first channel and the output bits of the second portion via a second channel, wherein the second channel is spatially different from the first channel.

In accordance with another aspect of the present invention, an apparatus for receiving information comprises receiving means for receiving the first portion of bits via a first channel and the second portion of bits via a second channel, combining means for combining the first and the second portions and decoding means for decoding the coded bitstream by removing redundancy from the coded bitstream, the decoding means using the first and second portions of bits combined by the combining means.

This inventive transmitter receiver concept provides the following advantages:

- two channels allow time and/or space diversity;

- the partitioner partitions rather than duplicates the output signal of the encoder into two portions of output bits;

- the combiner in the receiver combines rather than selects the signals received from both channels and feeds the combined signal into the channel decoder;

- the signals from both channels are used for decoding all the time;

- in the best case, in which the signal powers in both channels are identical, transmitter power used for

transmitting via each channel can be halved at least, thus, halving system costs with respect to the system illustrated in Fig. 7; and

- when the transmitter powers are not changed, the signal quality output by the channel decoder can be considerably improved.

The foregoing and other objects, features and advantages of the invention will become more readily apparent from the following detailed description of preferred embodiments which proceeds with reference to the drawings.

Fig. 1 shows a principle overview of a transmission receiving system in accordance with the present invention, comprising an inventive transmitter and an inventive receiver.

Fig. 2 shows a more detailed block diagram of the transmission receiving system shown in Fig. 1, in which time and space diversity are embodied.

Fig. 3 shows a detailed block diagram of an inventive transmitter section.

Fig. 4 shows an input bit sequence and an output bit pattern of a convolutional encoder used in an inventive transmitter section.

Fig. 5 shows a detailed view of an inventive receiver section.

Fig. 6 shows a generalised block diagram of a prior art transmitting receiving system.

Fig. 7 shows a block diagram of a transmitter receiver system implementing time and space diversity, in which the output of the transmitter encoder is

duplicated and a channel selection is performed in the receiver.

In Fig. 1 a general block diagram of an inventive apparatus for transmitting 100 and an inventive apparatus for receiving 200 is illustrated. The transmitting apparatus 100 comprises a bitstream source 110, a redundancy adding encoder 120 and a partitioner 130. The bitstream source 110 may be an MPEG encoder as described above. The encoder 120 is generally a redundancy adding encoder for generating an encoded bitstream on its output, wherein the encoder 120 is arranged to output, for a first number of input bits, a second number of output bits, the second number of output bits having at least twice as many output bits as the first number of input bits. This means that the encoder 120 implements a code rate equal to or less than 1/2. As it is known in the art, the code rate is defined by the number of input bits divided by the number of output bits produced by the encoder based on the number of input bits. In other words, a code rate 1/2 means that for each input bit, two output bits are produced. Analogously, a code rate of 1/3 means that for each input bit, three output bits are produced. Similarly, a code rate of 3/8 means that for three input bits, eight output bits are produced.

The code rate of the encoder 120 is set to be smaller than 1/2, such that the second number of output bits can be sub-divided into two portions of output bits, such that each portion of output bits individually allows the retrieval of information represented by the first number of input bits This means that a decoder 220 located in the receiving apparatus is able to retrieve information represented by the bitstream output by the bitstream source 110 when only one channel, i.e., channel 1 300 or channel 2 400 provides a useful signal, whereas the other channel has faded totally.

Another feature of the encoder 120 is that the first portion of output bit is coded based on the bitstream in a different

way with respect to the second portion of output bits. In contrast to a simple repetition code in which redundancy is doubled by simply duplicating a signal to transmitted coded, the channel decoder 220 capabilities are enhanced, since the signal is transmitted over the channels 300 and 400 are derived from the bitstream output by the bitstream source 110 independently of each other. The partitioner 130 feeds means for transmitting 140 for transmitting the first portion of output bits via the first channel 300 and the second portion of output bits via the second channel 400. It is to be noted that both channels 300 and 400 are spatially different from each other.

As usual, a channel between the transmitter and the receiver is defined by the line of sight connection between the transmitter and the receiver. Thus, two channels are different from each other when a mobile receiver has moved with respect to a single transmitter, or when two transmitters exist positioned in different locations, e.g., orbital positions. In this case, it does not play any role whether the receiver is a mobile or a stationary receiver.

Thus, the transmitting means 140 may comprise one transmitter, e.g., one satellite and a delay stage, such that two different channels are created between the single transmitter and a mobile receiver, when the mobile receiver is at a first position and between the single transmitter and the mobile receiver when the mobile receiver has moved to a second position after the period defined by the delay stage in the transmitter. This concept is called time diversity for mobile receivers. Naturally, it is not possible to create two channels different from each other between a single stationary transmitter and a stationary receiver.

Alternatively, as it is described with reference to Fig. 2, the transmitting means 140 comprise two transmitters positioned in different locations, to obtain space

diversity.

The receiving apparatus 200 illustrated in Fig. 1 comprises receiving means 240a and 240b, the receiving means comprising a first receiver 240a for receiving the first portion of output bits transmitted via the first channel 300 and a second receiver 240b for receiving the second portion of output bits via the second channel 400.

In accordance with the present invention, the output signals of the receiving means 240a and 240b are combined in a combiner 230 such that the output signals of both receivers are used in the channel decoder 220.

Fig. 2 illustrates a transmission receiving system in accordance with the preferred embodiment of the present invention. The transmitting apparatus comprises, as already described in Fig. 1, the bitstream source 110, the encoder 120 generally termed as forward error correction, the partitioner 130 and transmitting means comprising a first satellite 140a, a second satellite 140b and a delay stage 140c.

The receiving apparatus comprises the channel decoder 220, the combiner 230 and the receiving means (Rx) comprising the first and second receivers 240a, 240b and a delay stage 240c. The transmitting apparatus and the receiving apparatus are "connected" by the first channel 300 and the second channel 400.

By using the delay stages 140c and 240c, which are positioned in opposite channels, time diversity is implemented in the transmission receiving system shown in Fig. 2. Furthermore, by means of the provision of two transmitters, i.e., the first satellite 140a and the second satellite 140b, space diversity or spatial diversity is implemented into the inventive transmission receiving system.

With reference to Fig. 3, a more detailed block diagram of the transmitting apparatus is described. The encoder 120 in the transmitting apparatus is implemented as a convolutional encoder in accordance with the present invention. As it is shown in Fig. 3, the convolutional encoder comprises three generator polynominals, i.e., a first generator polynominal g1 121, a second generator polynominal g2 122 and a third generator polynominal g3 123. Thus, the convolutional encoder 120 has a code rate of 1/3, since, for one input bit, the encoder produces three output bits. The transmitting apparatus shown in Fig. 3 further comprises a puncturing unit 125 that reduces the number of bits, i.e., the number of output bits, such that an even number of output bits to be transmitted over the first and second channel is obtained. The puncturing unit 125 is connected to the partitioner 130, that, in accordance with the preferred embodiments of the present invention, comprises a parallel-to-serial converter and a demultiplexer to demultiplex the serial bitstream produced by the parallel-to-serial converter into two bitstreams. The block diagram in Fig. 3 further comprises the delay stage 140c of the transmitting means. The first transmitter and the second transmitter are not shown in Fig. 3.

Thus, the first portion of output bits is transmitted via the first channel, whereas the second portion of output bits is delayed by the delay stage, transmitted via the second channel.

With reference to Fig. 4, the functionality of the convolutional encoder 120, the puncturing unit 125 and the partitioner 130 will be described. In Fig. 4, an input bit sequence having bits 401, 402 and 403 is illustrated. The convolutional encoder 120 will produce three parallel arranged output bits 411, 412 and 413 for each input bit 401, 402 and 403. The notation of the output bits 411 to 413 relates to the channel, over which the respective bit is

transmitted. Thus, bits termed E are transmitted over the early satellite, i.e., satellite 140a (Fig. 2), whereas the bits termed L are transmitted over the late satellite, i.e., the satellite 140b (Fig. 2), which input is delayed by the delay stage 140c. The bit termed X is not transmitted at all. This bit is discarded by the puncturing unit 125 to obtain a second number of output bits, which is an even number. In accordance with the preferred embodiment of the present invention, an even number of output bits to be transmitted by the transmitting means 140 (Fig. 1) is required, since two channels exist and the number of bits transmitted over each channel are equal in the preferred embodiment. It has to be noted that equal numbers of bits in each channel are not esential for the present invention.

The output of the puncturing unit 125 is fed into a parallel-to-serial converter included in the combiner 130 (Fig. 3) such that a serial bitstream, i.e., the second number of output bits, is obtained. The demultiplexer included in the partitioner 130 demultiplexes the serial bitstream output by the parallel-to-serial converter into two bitstreams, in order to produce the first portion 410 and the second portion 420 of output bits.

It has to be noted that the number of bits in each of the first and second portions 410 and 420 is larger than the first number of input bits 401, 402 and 403 input into the convolutional encoder 120. Thus, some redundancy still exists to be used by the channel decoder 220 (Fig. 2), when one channel is totally lost, for instance, when a mobile receiver is under a bridge. In general, however, it is not required that the first and second portion of output bits comprise more bits than the first number of input bits, since both portions together still have a code rate of 1/2, whereas each portion of output bits 410, 420 has a code rate of 1 when the convolutional encoder 120 has a code rate of 1/2.

Referring back to Fig. 4, a convolutional encoder having a code rate of 3/8 is described. This means that for a first number of input bits, the first number being 3, a second number of output bits, the second number being 8, is produced.

Referring to Fig. 5, a preferred embodiment of the receiving apparatus is described. Optionally, the receiving means comprises a QPSK demodulator 240d for receiving the first channel and a QPSK demodulator 240e for receiving the second channel. Naturally, the QPSK demodulators 240d and 240e only have to be provided when the transmitting apparatus has performed a QPSK modulation. The output of the QPSK demodulator is fed into the delay stage 240c and then into a multiplexer 230a. The output of the QPSK demodulator 240e is directly fed into the multiplexer 230a. Thus, the multiplexer 230a receives the first portion of output bits (410 in Fig. 4) and the second portion of output bits (420 in Fig. 4) for producing one single serial bitstream comprised of the first portion and the second portion. This continuous serial bitstream is input into a depuncturing unit 230b for undoing the puncturing carried out by the puncturing unit 125 (Fig. 3).

Then, the depunctured bitstream, i.e., the combined bitstream output by the combiner that comprises the multiplexer 230a and the depuncturing unit 230b, is input into the channel decoder that, in accordance with the preferred embodiment of the present invention, comprises the Viterbi decoder 220a and a Reed-Solomon decoder 220b. Those skilled in the art will know that the Reed-Solomon decoder only has to be provided when a Reed-Solomon coding has been carried out in the transmitting apparatus. In accordance with the preferred embodiment of the present invention, the transmitting apparatus causes a concatenated forward error correction encoder having a convolutional encoder and a Reed-Solomon encoder. Thus, the receiving apparatus has to comprise a Viterbi decoder 220a and a Reed-Solomon decoder

220b. It is known in the art that convolutional encoders may create small burst errors. The Reed-Solomon encoder, however, is well suited for such burst errors.

In the following, the inventive transmitting receiving system illustrated in Fig. 1, which makes use of an encoder having a code rate less than 1/2, and has a partitioner and a combiner is compared to the transmission receiving system shown in Fig. 7 that makes use of a duplicator and a channel decision controlled switch.

To ease the comparison of both systems, it is assumed that the encoders 120 (Fig. 1) and 64 (Fig. 7) comprise a convolutional encoder and a Reed-Solomon encoder. Furthermore, it is assumed that the convolutional encoder included in the redundancy adding encoder 120 of Fig. 1 implements a code rate of 3/8, whereas the convolutional encoder included in the redundancy adding encoder 64 of Fig. 7 encodes based on a code rate of 3/4. Since the transmitting apparatus shown in Fig. 7 transmits eight output bits for three input bits, i.e., the duplicator effectively doubles the output bits to be transmitted, it can be regarded as a redundancy adding encoder having a code rate of 3/8. The signals transmitted over the first and the second channels, however, are identical and identically derived from the bitstream output by the bitstream source 62.

According to the code rate of 3/4 (convolutional coder only), for three information bits, four channel bits are transmitted over each satellite in the system of Fig. 7 Using two satellites, eight channel bits are transmitted for three information bits. Thus, it is clear that the system shown in Fig. 7 can be regarded as a system having a code rate of 3/8.

According to the literature and system simulation results, the following E_b/N_0 performance can be assumed. It is noted

that the term E_b/N_0 represents the ratio of the energy per useful bit rate (unit factor: W/sec) to noise power density (unit facor: W/sec). Thus, the "unit factor" of E_b/N_0 is 1. For QPSK, the C/N (= Power of transmitted signal/noise power within effective bandwidth) can be calculated by the following equation:

$C/N = E_b/N_0 + 10 \cdot \log(R) + 3$ dB (C/N and E_b/N_0 values in dB)

In this equation, R is the code rate. It is to be noted that the term C/N represents the "link margin". If the real C/N is higher than the link margin, a useful communication link is obtained. If the real C/N is lower than the C/N defined by the above-outlined equation, no satisfying communication link can be established.

The following Table gives the C/N in dB for three different code rates. The first line of the Table relates to the system shown in Fig. 7, whereas the third line of the Table relates to the inventive system shown in Fig. 1. The factor (223/255) relates to the Reed-Solomon encoder. The factors 3/4, 1/2 and 3/8 relate to the convolutional coders "Rate".

Table

Code rate (convol. + Reed-Solomon)	Eb/N0 [dB]	C/N [dB]
3/4 * (223/255) = 0.66	3.7	4.9
1/2 * (223/255) = 0.44	2.7	2.1
3/8 * (223/255) = 0.33	app. 2.4	**0.6**

In the following, the Table is explained. The required C/N value also applies to a system where the bitstream is de-multiplexed to two streams and transmitted using two QPSK modulators. The overall transmitted power is defined as:

$$C = C_{sat1} + C_{sat2}.$$

The noise power is defined as follows:

$$N = N_1 + N_2.$$

It is assumed that the signal power is identical for satellites 1 and 2, which is the best case for the inventive method. With $N_1 = N_2$ and $C_{Sat1} = C_{Sat2}$ (the effective bandwidth is identical for both signals, i.e., channels), the following equation applies:

$$\frac{C}{N} = \frac{C_{Sat1} + C_{Sat2}}{N_1 + N_2} = \frac{2C_{Sat1}}{2N_1} = \frac{C_{Sat1}}{N_1} = \frac{C_{Sat2}}{N_2}$$

Assuming the available signal power (= C) and the QPSK symbol rate are kept, the method in accordance with the present invention can give a gain of **4.3 dB** compared to the

required C/N, if one signal is decoded only (system of Fig. 7). It is assumed that for other scenarios, i.e., both channels show different fading characteristics, the gain is lower. At least for the scenario C_{Sat1}/N or C_{Sat2}/N being greater than 4.9 dB, no gain is required. The output signal is error free in any case. The overall gain of the inventive transmission receiving system depends on the probability of the scenario. In other words, it is possible to receive the signal down to a C/N of 0.6 dB, which is a theoretical value that does not include implementation loss. If only one satellite signal is available, the required C/N_0 is equal to 67 dBHz (not including implementation loss). The unit factor dBHz represents power divided by power density in logarithmical terms.

As it has been described with respect to Figs. 3 and 4, a convolutional encoder with a code rate of 1/3 is preferred The output of the convolutional enocoder is punctured to a code rate of 3/8 by not transmitting one channel bit out of 9. The output of the convolutional encoder and puncturing unit is converted into a serial form and demultiplexed. Four bits out of 8 are transmitted over satellite 1, i.e., the first portion of output bits. The other four bits are transmitted over satellite 2, i.e., the second portion of output bits. Optionally, an additional time interlever can be used.

As it has been outlined in the introductory portion, the polynominals g1, g2 and g3 describe the shift registers and modulo-2 adders or XOR gates which generate the convolutional code having a code rate of 1/3. The proposed polynominals are as follows:

g1 = 1 1 0 0 1 1 1 (binary) = 147 (octal)
g2 = 1 0 1 1 1 0 1 (binary) = 135 (octal)
g3 = 1 1 1 0 0 1 1 (binary) = 163 (octal)

It should be noted that generator polynomials different from

the above mentioned generator polynomials combined with certain puncturing schemes may be used as well (see J. Bibb Cain *supra*). However, the above given generator polynomials work very well in connection with the puncturing scheme described herein.

The receiver shown in Fig. 5 requires one Viterbi decoder only. The optimal combining with respect to the signal quality of the two signals is automatically performed by the Viterbi decoder. The Viterbi decoder performs maximum likelihood decoding using the channel state information, also called "metric". Algorithms known for Rician and Rayleigh channels can be adapted. If only one signal is available, i.e., one channel is faded totally, the input of the Viterbi decoder can be considered as a convolutional encoder having a code rate of 1/3 punctured to a code rate of 3/4. The equivalent puncturing scheme is:

For the early satellite

1 1 1
1 0 0
0 0 0

and for the late satellite

0 0 0
0 0 1
1 1 1.

In accordance with a preferred embodiment of the present invention, a Viterbi decoder implementing a soft decision based on probabilities is used. Thus, the depuncturing unit inserts probabilities rather than actual bit states. Since the depuncturing unit does not have any information about the bits punctured by the puncturing unit in the transmitting apparatus, it inserts probabilities of 0.5 for the low and the high states of the bits.

Optionally, the combiner 230 (Fig. 1) additionally comprises a channel estimator, that evaluates the signal to noise ratio of signals received from each channel. When the channel estimator determines low signal to noise ratios, it is adapted to insert 0.5 probabilities rather than the actual probabilities derived from the channel having a low signal to noise ratio. Thus, it can be ascertained that the maximum likelihood decoder is not misled by signals received via a channel having a low signal to noise ratio.

Although the preferred embodiment of the present invention has been described with respect to two channels, the inventive concept can also be applied to a transmission system comprising three or more channels. In the case of three channels, the code rate of the channel encoder 120 (Fig. 1) is to be 1/3 or less. Additionally, the partitioner produces three portions of output bits rather than two portions of output bits. In this case, the transmitting apparatus as described in Fig. 3 can be used. However, no puncturing unit is necessary and the demultiplexer multiplexes three bitstreams, one for each of the three channels. After reading this specification, it is obvious for those skilled in the art that the present invention even can be extended to four or more channels.

Although the preferred embodiment of the present invention uses a convolutional encoder which is optionally extended by means of a Reed-Solomon encoder, other redundancy adding encoders can be adapted. These redundancy adding encoders, however, have to produce two portions of output bits that are coded differently with respect to each other, such that a "real" code rate of, for example, 3/8 in contrast to a doubled 3/4 code rate can be obtained.

The delay imposed by the different delay stages can be set in accordance with the real environment. Normally, a delay of four seconds is regarded as appropriate. However, other

delay values can be adapted. It is to be noted, however, that high delay values result in high memory capacities for the transmitter and the receiver.

Claims

1. Apparatus (100) for transmitting information, comprising:

a bitstream source (110) for providing a bitstream representing the information;

a redundancy adding encoder (120) for generating an encoded bitstream (411, 412, 413) based on the bitstream (401, 402, 403) provided by the bitstream source (110) wherein the encoder (120) is arranged to output, for a first number of input bits (401 to 403), a second number of output bits, the second number of output bits having at least twice as many output bits as the first number of input bits, and wherein the second number of output bits includes two portions (410, 420) of output bits, each portion (410, 420) of output bits individually allowing the retrieval of information represented by the first number of input bits (401 to 403), and the first portion (410) of output bits being coded based on the bitstream in a different way with respect to the second portion (420) of output bits;

means for partitioning (130) the second number of output bits into the two portions (410, 420) of output bits; and

means for transmitting (140) the output bits of the first portion (410) via a first channel (300) and the output bits of the second portion (420) via a second channel (400), the second channel (400) being spatially different from the first channel (300).

2. Apparatus of claim 1, in which:

the means for transmitting (140) includes a single transmitter;

the first channel (300) is defined by the single transmitter and a first position of a mobile receiver;

the second channel (400) is defined by the single transmitter and a second position of the mobile receiver; and

the means for transmitting (140) further includes delay means for delaying the second portion (420) of output bits transmitted via the second channel (400) such that time diversity is obtained.

3. Apparatus of claim 1, in which:

the means (140) for transmitting includes a first transmitter (140a) and a second transmitter (140b) spaced apart from the first transmitter;

the first channel (300) is defined by the first transmitter (140a) and the receiver; and

the second channel (400) is defined by the second transmitter (140b) and the receiver such that space diversity is obtained.

4. Apparatus of claim 3, in which:

the first and second transmitters (140a, 140b) include two satellites in different orbital positions, such that the first channel (300) is defined by an uplink connection from earth to the first satellite (140a) and a downlink connection from the first satellite to a receiver on earth, and such that the second channel (400) is defined by a uplink connection from earth to the second satellite and a downlink connection from the second satellite to the receiver on earth.

5. Apparatus of claim 3, in which:

one transmitter includes a satellite; and

the other transmitter includes a terrestrial sender such that terrestrial diversity is obtained.

6. Apparatus of any one of claims 3 to 5, in which the means for transmitting (140) further includes delay means (140c) for delaying the second portion (420) of output bits transmitted via the second channel (400) such that time diversity is obtained.

7. Apparatus of any one of the preceding claims, in which:

the redundancy adding encoder (120) includes a convolutional encoder for obtaining a code rate less than or equal to 0.5, wherein the code rate is the ratio of the first number of input bits (401 to 403) to the second number of output bits (411 to 413), the convolutional encoder (120) combining a current input bit to be encoded with at least one of a certain number of preceding input bits.

8. Apparatus of claim 7, in which:

the certain number of preceding bits is 6; and

the convolutional encoder (120) comprises three generator polynominals g_1, g_2 and g_3 (121 to 123) having the following binary form:

g_1 = 1 1 0 0 1 1 1,
g_2 = 1 0 1 1 1 0 1, and
g_3 = 1 1 1 0 0 1 1.

9. Apparatus of claim 7 or 8 which further comprises a puncturing unit (125) operative to discard at least one predetermined bit of the encoded bitstream such that the second number of output bits is an even number, wherein the first and second portions (410, 420) of output bits comprise the same number of output bits.

10. Apparatus of any of the preceding claims, in which:

the redundancy adding encoder (120) is operative to code the bitstream provided by the bitstream source (110) in a bit-by-bit fashion;

the means for partitioning (130) includes a parallel storage for storing a predetermined amount of output bits of the convolutional encoder (120);

a parallel-to-serial converter for producing a serial stream of the stored bits to be partitioned into the first and second portion (410, 420) of output bits is provided; and

a de-multiplexer (130) for performing the partition of the serial stream of output bits into the first and second portions (410, 420) is provided.

11. Apparatus for receiving information, the information being represented by an encoded bitstream, the encoded bitstream being encoded such that its redundancy is at least doubled with respect to a bitstream from which the encoded bitstream is derived, and that, for a first number of bits of the bitstream, the encoded bitstream comprises a second number of bits, the second number of bits having at least twice as many bits as the first number, and wherein the second number of bits includes two portions (410, 420) of bits, each portion (410, 420) of bits individually allowing the retrieval of information represented by the first number (401 to 403) of bits, and the first portion (410) of the bits being encoded in a different way with respect to the second portion (420) of bits, the apparatus comprising:

receiving means (240a, 240b, 240c) for receiving the first portion (410) of bits via a first channel (300) and the second portion (420) of bits via a second channel (400),

the first and the second channels being spatially different from each other;

combining means (230) for combining the first and the second portions (410, 420); and

decoding means (220) for decoding the coded bitstream by removing redundancy from the coded bitstream, the decoding means using the first and second portions (410, 420) of bits combined by the combining means (230).

12. Apparatus of claim 11, in which the receiving means (240a, 240b, 240c) further includes delay means (240c) for delaying the portion (410) of bits received via one channel (300) to compensate for a delay imposed on the portion (420) of bits received via the other channel (400).

13. Apparatus of claim 12, in which the combining means (230) includes a multiplexer (230a) for multiplexing first and second portions (410, 420) into a form suitable for the decoding means (220).

14. Apparatus of any of the claims 11 to 13, in which the combining means (230) further includes a depuncturing unit (230b) for performing a depuncturing operation on the first and second portions (410, 420) of bits to compensate for a puncturing operation performed in a transmitter.

15. Apparatus of any of the claims 11 to 14, in which:

the decoding means (220) comprises a soft decision decoder processing probabilities in that a received bit represents a high or low state rather than an actual wave form characteristic of the received bitstream; and

depuncturing means for compensating for a puncturing operation in a transmitter is provided and attributes to a bit to be depunctured equal probabilites for the high and

low states.

16. Apparatus of claim 15 in which the decoding means (220) includes a Viterbi decoder (220a) performing maximum likelihood decoding using the state information of the first and second channels (300, 400).

17. Apparatus of claim 15 or 16 in which:

the decoding means (220) comprises a signal to noise ratio evaluating means for determining a channel having a low signal to noise ratio; and

a bit replacing means for replacing the bits of a portion of bits received via a channel having a low signal to noise ratio by values equivalent to a lower reliability for the high and low states.

18. Apparatus of claim 16 or 17 in which the decoding means (220) further comprises a Reed-Solomon decoder (220b) fed by the Viterbi decoder (220a) for undoing a Reed-Solomon encoding performed in the transmitter.

19. Apparatus of any of the claims 11 to 19 in which the receiving means (240) comprises, for each channel (300, 400), a QPSK demodulator (240d, 240e) for providing the first and the second portions (410, 420) of bits.

20. Method (100) for transmitting information, comprising the following steps:

providing (110) a bitstream representing the information;

generating (120) a redundancy added encoded bitstream (411, 412, 413) based on the bitstream (401, 402, 403) provided in the step of providing, wherein for a first number of input bits (401 to 403), a second number of output

bits is generated, the second number of output bits having at least twice as many output bits as the first number of input bits, and wherein the second number of output bits includes two portions (410, 420) of output bits, each portion (410, 420) of output bits individually allowing the retrieval of information represented by the first number of input bits (401 to 403), and the first portion (410) of output bits being coded based on the bitstream in a different way with respect to the second portion (420) of output bits;

partitioning (130) the second number of output bits into the two portions (410, 420) of output bits; and

transmitting (140) the output bits of the first portion (410) via a first channel (300) and the output bits of the second portion (420) via a second channel (400), the second channel (400) being spatially different from the first channel (300).

21. Method of claim 20, in which:

the step of transmitting (140) is performed by a single transmitter;

the first channel (300) is defined by the single transmitter and a first position of a mobile receiver;

the second channel (400) is defined by the single transmitter and a second position of the mobile receiver; and

the step of transmitting (140) comprises the following substeps: transmitting the first portion of output bits; and delaying the second portion (420) of output bits before transmitting via the second channel (400) such that time diversity is obtained.

22. Method of claim 20, in which:

the step of transmitting (140) is carried out by a first transmitter (140a) and a second transmitter (140b) spaced apart from the first transmitter;

the first channel (300) is defined by the first transmitter (140a) and the receiver; and

the second channel (400) is defined by the second transmitter (140b) and the receiver such that space diversity is obtained.

23. Method of claim 22, in which:

the first and second transmitters (140a, 140b) include two satellites in different orbital positions, such that the first channel (300) is defined by an uplink connection from earth to the first satellite (140a) and a downlink connection from the first satellite to a receiver on earth, and such that the second channel (400) is defined by a uplink connection from earth to the second satellite and a downlink connection from the second satellite to the receiver on earth.

24. Method of claim 22, in which:

one transmitter includes a satellite; and

the other transmitter includes a terrestrial sender such that terrestrial diversity is obtained.

25. Method of any one of claims 22 to 24, in which the step of transmitting (140) further includes the following substeps: delaying (140c) the second portion (420) of output bits transmitted via the second channel (400) such that time diversity is obtained.

26. Method of any one of the claims 20 to 25, in which:

the step of generating is carried out by means of a convolutional encoder for obtaining a code rate less than or equal to 0.5, wherein the code rate is the ratio of the first number of input bits (401 to 403) to the second number of output bits (411 to 413), the convolutional encoder (120) combining a current input bit to be encoded with at least one of a certain number of preceding input bits.

27. Method of claim 26, in which:

the certain number of preceding bits is 6; and

the convolutional encoder (120) comprises three generator polynominals g_1, g_2 and g_3 (121 to 123) having the following binary form:

g_1 = 1 1 0 0 1 1 1,
g_2 = 1 0 1 1 1 0 1, and
g_3 = 1 1 1 0 0 1 1.

28. Method of claim 26 or 27 which further comprises the step of puncturing (125) to discard at least one predetermined bit of the encoded bitstream such that the second number of output bits is an even number, wherein the first and second portions (410, 420) of output bits comprise the same number of output bits.

29. Method of any one of the claims 20 to 28, in which:

the step of generating comprises coding the bitstream provided by the bitstream source (110) in a bit-by-bit fashion;

the step of partitioning (130) includes the step of storing, in a parallel way, a predetermined amount of output bits;

the step of parallel-to-serial converting for producing a serial stream of the stored bits to be partitioned into the first and second portion (410, 420) of output bits is carried out; and

the step of de-multiplexing (130) for performing the partition of the serial stream of output bits into the first and second portions (410, 420) is carried out.

30. Method for receiving information, the information being represented by an encoded bitstream, the encoded bitstream being encoded such that its redundancy is at least doubled with respect to a bitstream from which the encoded bitstream is derived, and that, for a first number of bits of the bitstream, the encoded bitstream comprises a second number of bits, the second number of bits having at least twice as many bits as the first number, and wherein the second number of bits includes two portions (410, 420) of bits, each portion (410, 420) of bits individually allowing the retrieval of information represented by the first number (401 to 403) of bits, and the first portion (410) of the bits being encoded in a different way with respect to the second portion (420) of bits, the method comprising the following steps:

receiving (240a, 240b, 240c) the first portion (410) of bits via a first channel (300) and the second portion (420) of bits via a second channel (400), the first and the second channels being spatially different from each other;

combining (230) the first and the second portions (410, 420); and

decoding (220) the coded bitstream by removing redundancy from the coded bitstream, wherein the first and second portions (410, 420) of bits combined in the step of combining (230) are used in the step of decoding (220).

31. Method of claim 30, in which the step of receiving (240a, 240b, 240c) further includes the step of delaying (240c) the portion (410) of bits received via one channel (300) to compensate for a delay imposed on the portion (420) of bits received via the other channel (400).

32. Method of claim 31, in which the step of combining (230) includes the step of multiplexing (230a) the first and second portions (410, 420) into a form suitable for the step of decoding (220).

33. Method of any of the claims 30 to 32, in which the step of combining (230) further includes the step of depuncturing (230b) performing a depuncturing operation on the first and second portions (410, 420) of bits to compensate for a puncturing operation performed in a transmitter.

34. Method of any of the claims 30 to 33, in which:

the step of decoding (220) comprises the step of soft decision decoding to process probabilities such that a received bit represents a high or low state rather than an actual wave form characteristic of the received bitstream; and

a step of depuncturing for compensating for a puncturing operation in a transmitter is carried out and attributes to a bit to be depunctured equal probabilites for the high and low states.

35. Method of claim 34 in which the step of decoding (220) includes a Viterbi decoder (220a) **performing maximum** likelihood decoding using the state information of the first and second channels (300, 400).

36. Method of claim 34 or 35, in which:

the step of decoding (220) includes the step of signal to noise ratio evaluating for determining a channel having a low signal to noise ratio; and

the step of bit replacing for replacing the bits of a portion of bits received via a channel having a low signal to noise ratio by equal probabilities for the high and low states is carried out.

37. Method of claim 35 or 36 in which the step of decoding (220) further comprises a Reed-Solomon decoder (220b) fed by the Viterbi decoder (220a) for undoing a Reed-Solomon encoding performed in the transmitter.

38. Method of any of the claims 30 to 38, in which the step of receiving (240) comprises, for each channel (300, 400), the step of QPSK demodulating (240d, 240e) for providing the first and the second portions (410, 420) of bits.

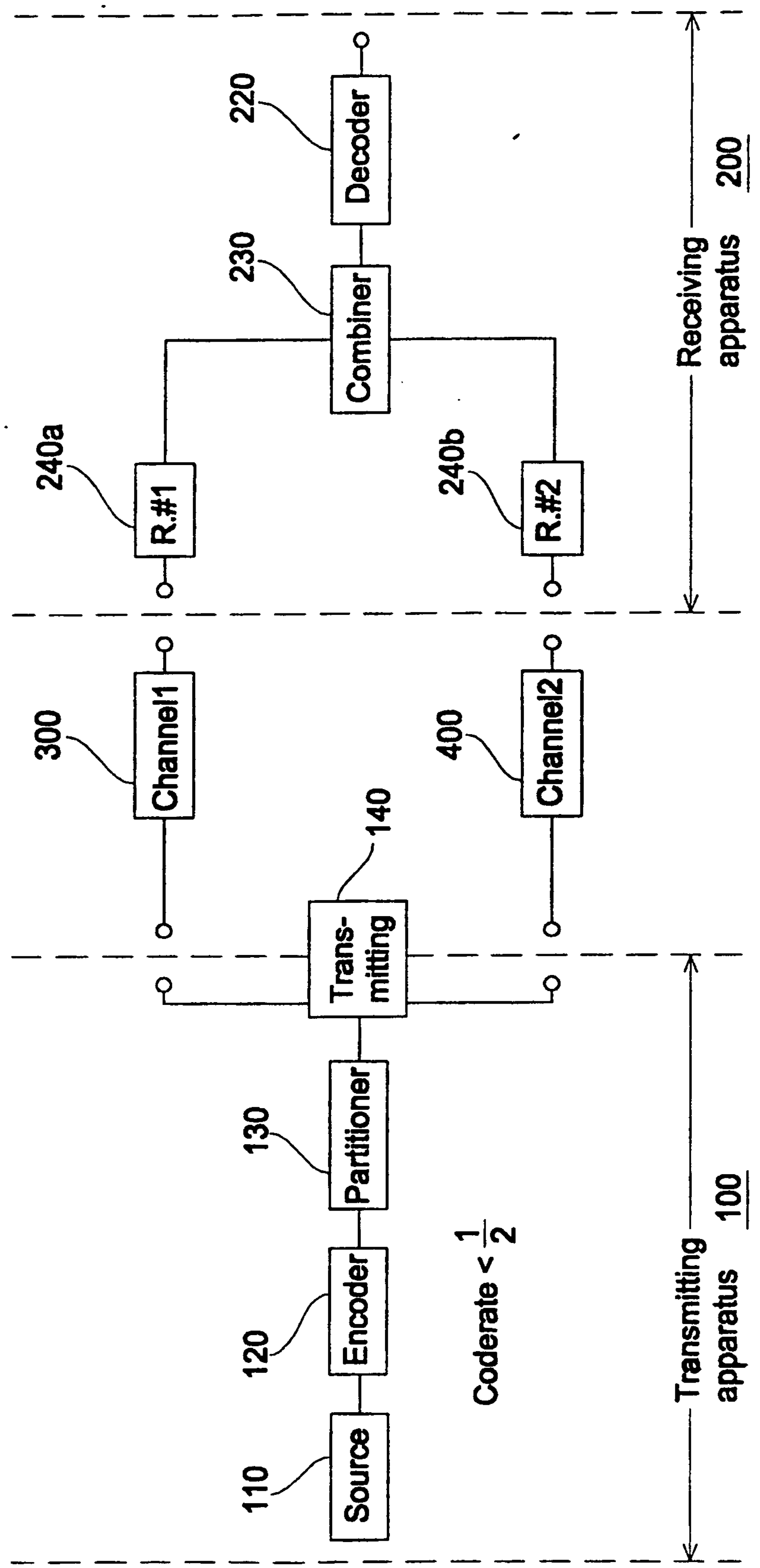
Source
110
Encoder
120
Coderate < 1/2
Partitioner
130
Trans-
mitting
140
Channel1
300
Channel2
400
R.#1
240a
R.#2
240b
Combiner
230
Decoder
220
Transmitting apparatus
100
Receiving apparatus
200

Fig. 1

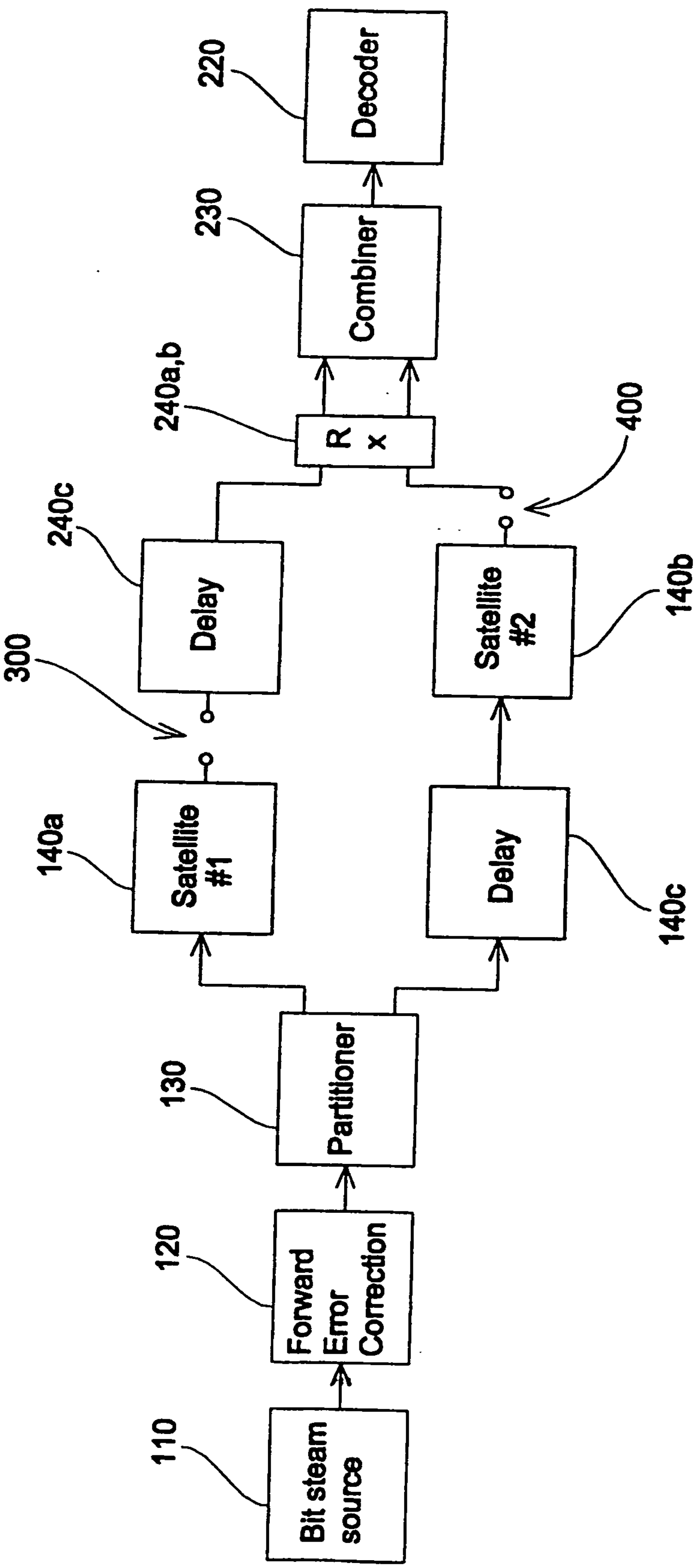
110
Bit steam source
120
Forward Error Correction
130
Partitioner
140a
Satellite #1
140c
Delay
300
240c
Delay
140b
Satellite #2
400
240a,b
R x
230
Combiner
220
Decoder

Fig. 2

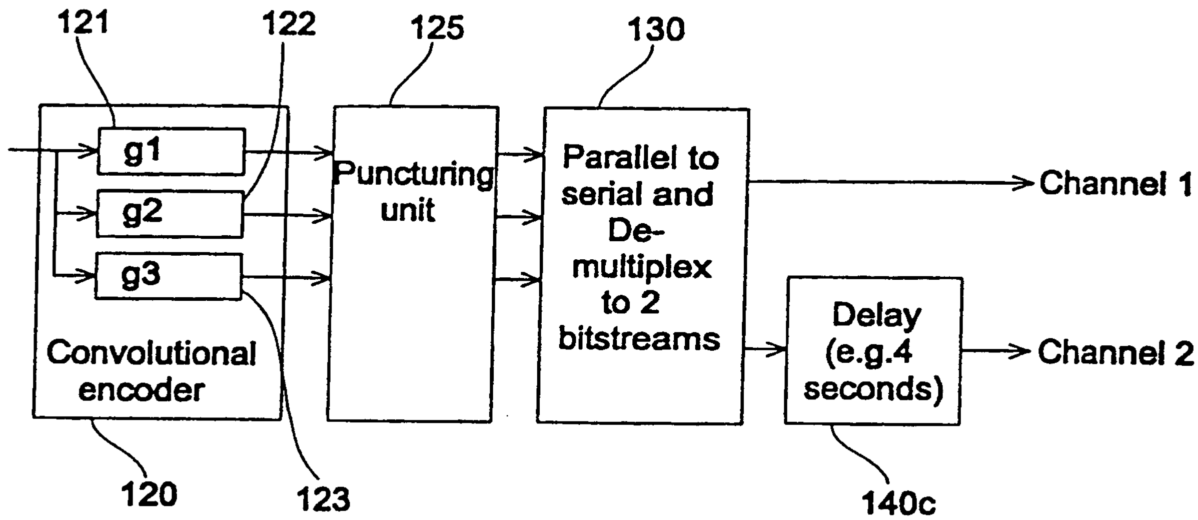
121
122
125
130
g1
g2
g3
Convolutional encoder
Puncturing unit
Parallel to serial and De-multiplex to 2 bitstreams
Channel 1
Delay (e.g.4 seconds)
Channel 2
120
123
140c

Fig. 3

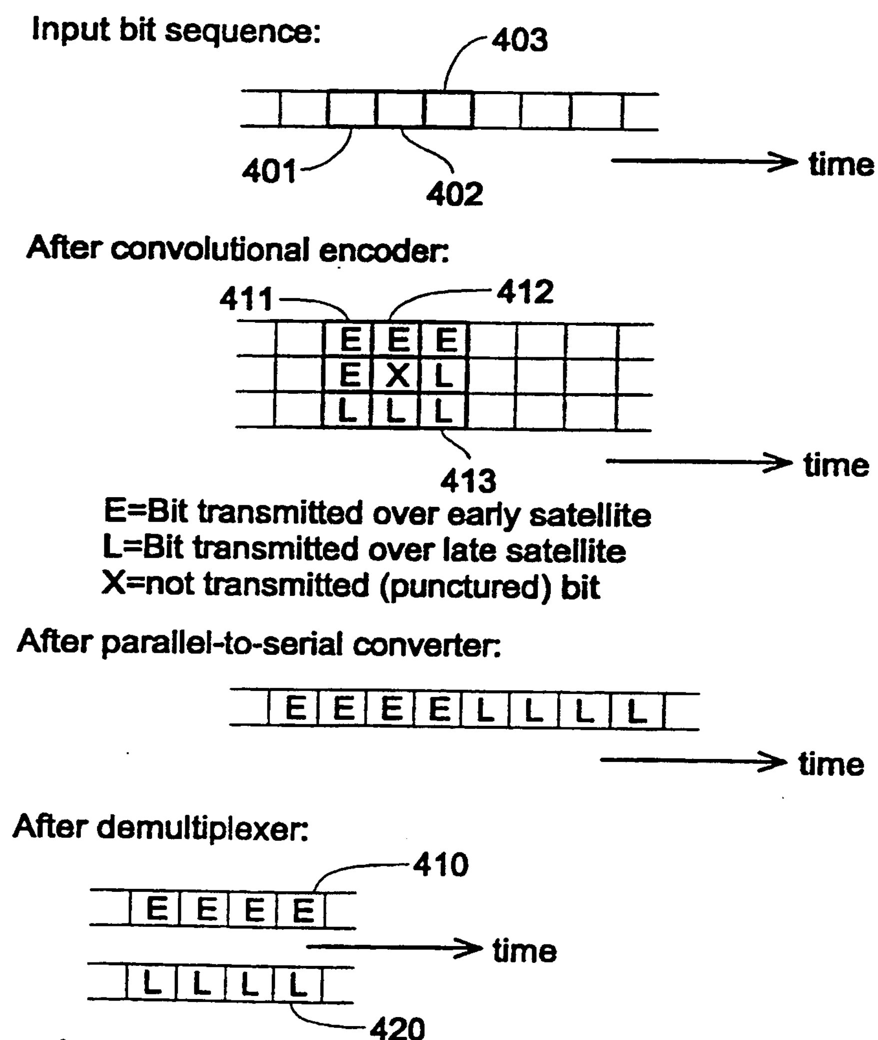
Input bit sequence:
403
401
402
time
After convolutional encoder:
411
412
E E E
E X L
L L L
413
time
E=Bit transmitted over early satellite
L=Bit transmitted over late satellite
X=not transmitted (punctured) bit
After parallel-to-serial converter:
E E E E L L L L
time
After demultiplexer:
410
E E E E
time
L L L L
420

Fig. 4

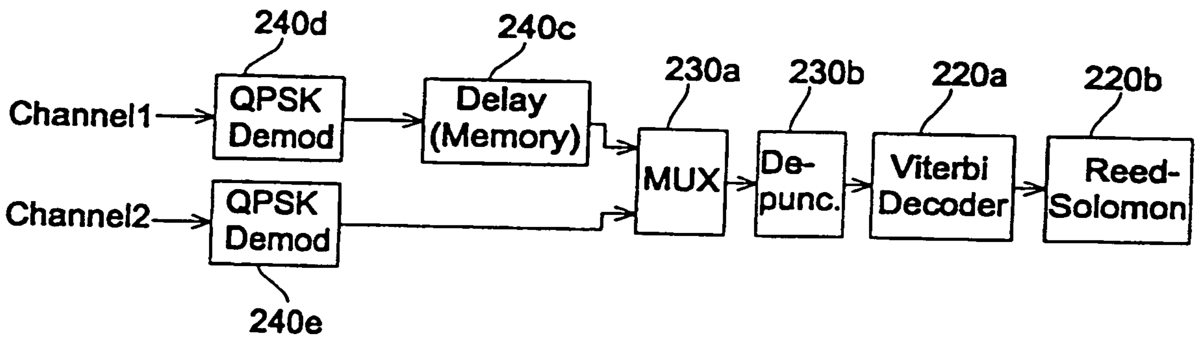

Fig. 5

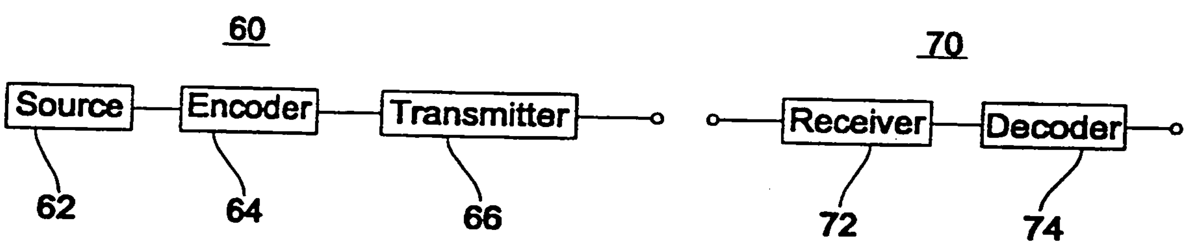

Fig. 6

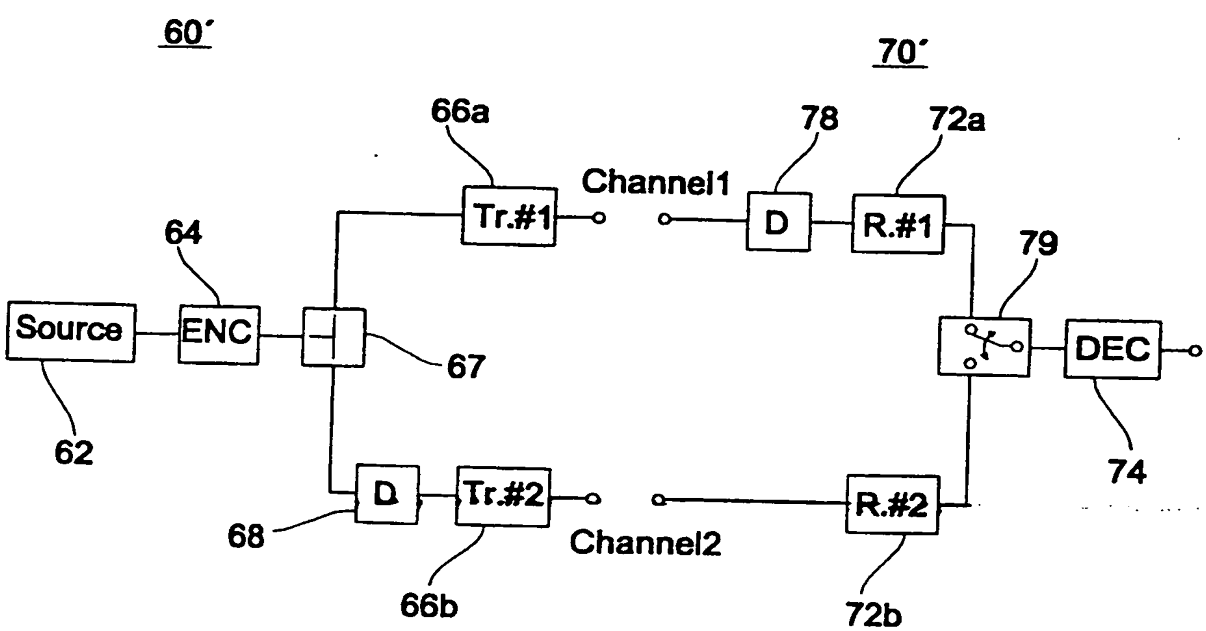

Fig. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/07850

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L1/06 H04B7/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BENELLI G: "TWO NEW CODING TECHNIQUES FOR DIVERSITY COMMUNICATION SYSTEMS" IEEE TRANSACTIONS ON COMMUNICATIONS, vol. 38, no. 9, 1 September 1990 (1990-09-01), pages 1530-1538, XP000173221 ISSN: 0090-6778	1-3,7, 10,11, 20,22, 26,29,30
Y	abstract column 1, line 1 - column 4, line 1 figures 1-3 ---	6,9,21, 25,28
Y	US 5 657 325 A (LOU HUI LING ET AL) 12 August 1997 (1997-08-12) abstract column 1, line 1 - column 4, line 15 figures 1A,2,3 ---	9,28
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 August 1999	25/08/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gautier, L

1

International Application No
PCT/EP 98/07850

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 572 171 A (AMERICAN TELEPHONE & TELEGRAPH) 1 December 1993 (1993-12-01) abstract page 2, line 1 - page 4, line 31 figures 2,3,4A,5 ---	6,21,25
A	ALAMOUTI S M: "A simple transmit diversity technique for wireless communications" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, vol. 16, no. 8, October 1998 (1998-10), pages 1451-1458 1458, XP002100058 ISSN: 0733-8716 the whole document -----	1,11,20, 30

1

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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTER●TIONAL SEARCH REPORT

Information on patent family members

Int●onal Application No
PCT/EP 98/07850

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5657325 A	12-08-1997	US 5689439 A	18-11-1997
		CA 2172320 A	01-10-1996
		EP 0735701 A	02-10-1996
		CA 2171998 A	04-10-1996
		EP 0736979 A	09-10-1996
		JP 8288934 A	01-11-1996
EP 0572171 A	01-12-1993	US 5305353 A	19-04-1994
		CA 2094193 A,C	30-11-1993
		JP 2859513 B	17-02-1999
		JP 6037683 A	10-02-1994
		US 5457712 A	10-10-1995

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